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FABRICATION AND INVESTIGATION OF THE DEFORMATION BEHAVIOUR OF AL-SI VARYING REINFORCED WITH GRAPHITE AND GRANITE COMPOSITES

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ABSTRACT

In this Experimental work the deformation behavior of solid A356varying reinforced with graphite and granite composite cylinders under axisymmetric compression over different aspect ratios without using any lubricant was examined. Two different aspect ratios namely 1.0 and 1.5 were prepared and cold upset forged. Study was carried out to generate data on the upset forging of solid cylinders of alloy and composites. The curvatures of the barreled aluminium cylinders measured physically were found to conform closely to the values calculated using the experimental data. The specimens were carried on INSTRON machine for accurate values. "Bulge diameter for base Al-Si alloy and its composites increased with increasing degree of deformation, due to friction at contact surfaces, where as radius of curvature of bulge decreased with increasing degree of deformation".

KEYWORDS: Aspect ratio, A356, Deformation behavior, Graphite, Granite & INSTRON

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Original Article

1. INTRODUCTION

Metal Matrix composites (MMCs) are becoming gorgeous materials for advanced aerospace and automobile structures because of their properties can be customized through the addition of selected reinforcements [1]. "Due to the high specific stiffness and strength at room or high temperatures the particle reinforced metal matrix composites are used. Normally micron sized ceramic particles are used as reinforcement to improve the properties of the MMCs. Fly ash is the lowest density and economical reinforcement obtainable in bulk quantities as waste by product after incineration of coal in power plants". Hassan S. F et al. [2] studied "the characterization and SEM examination of SiC as reinforcement in metal matrix composites which are fabricated by secondary processing methods like extrusion and identified higher strain to failure values for the extruded material also sinter forged test showed the higher value of elastic modulus and Ultimate tensile strength because of failure in particle due to fracture".

The lower strains were observed for inferior bonding among the matrix and reinforcing particles when compared to deform one. Ma et al [3] reported that "incorporating ceramic particles in A356 matrix weakens the interfacial bonding and in due course resulting in the pull-out of the SiC particle. The lattice straining in the adjacent areas of the particles will reduce the extent of plastic deformation that these areas can undergo, which will make them more vulnerable to cracking". These cracks will result in the removal of the matrix from adjoining areas of the particles, thus decreasing the strength of interfacial bond. In the present work an attempt has been made to get excellent properties of high specific strength with good wear resistant properties.

2. FABRICATION OF COMPOSITES

Al-Si alloy was melted at 775^0C under the protection of argon inert gas atmosphere. The reaction slag was skimmed from the surface of melt. Granite and graphite particles were added into the vortex formed during stirring. Al-Si alloy based composites were kept as constant and by varying the graphite 2% and granite 2-4 % in the form of 8inch long x 25mm Diaand 8inch long x 22mm Dia castings as shown in the Figure 1 and Figure 2."Homogenization treatment was carried out at 200^0C for 24 h to relieve the internal stresses and minimize the chemical in homogenities, which may be present in the cast alloys. The cylindrical test specimens of size 12mm length x 12mm diameter with aspect ratio 1 and 18mm length x12mm diameter for aspect ratio 1.5 were machined from the castings for deformation studies".

Table 1: Chemical Composition of Al-Si Alloy, wt%.

Si	Mg	Cu	Fe	Ti	Al
6.5	0.4	0.05	0.09	0.06	balance

Figure 1: Casted Fingers in CI Die of base Alloy and Composite 1.

Figure 2: Casted Fingers in CI Die of Composite 2 and Composite 3.

3. COMPRESSION TEST

The upset tests were performed at room temperature between two flat plates on a Fatigue testing machine (INSTRON Model: 8801) as shown in figure 3. "The compression dies of EN-31 grade isutilized for compression and also the sample was placed axi-symmetrically in between the dies. The tests were conducted at 10%, 20%, 30%, 40% and 50% deformations on the top surface of the Al-Si alloy and its composites with a constant cross head speed to assess the

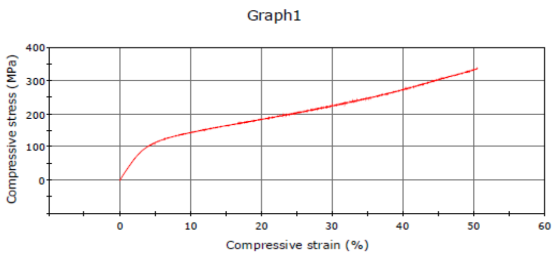
deformation behaviour for two limiting values of aspect ratio 1.5 (to avoid buckling) and 1.0 (which is used in most of the forging applications)".

Figure 3: Shows the Deformation of Specimen with INSTRON.

Table 2: Compressive Strength for H/D 1.0 and 1.5

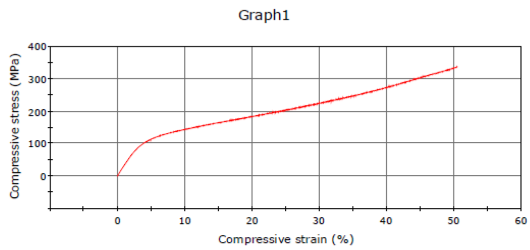
Sl. No	Specimen	Compressive Strength(Mpa)-H/D (1.0)	Compressive Strength(Mpa)-H/D (1.5)
1	Base A356	382	336
2	A356+2%Graphite	531	484
3	A356+2%Graphite+2%Granite	662	583
4	A356+2%Graphite+4%Granite	554	504

Compression properties of both alloy and composites were determined by means of INSTRON testing machine as per the standards, as shown in figure 4 and figure 5. Plotting has done continuously through a data attainment system with an electronic extensometer. The fractured specimens were shown in figure 6. The composite with 2 % graphite and 2 % granite (C2) showed improved compression strength and maximum load of composite when compared to the base matrix and remaining reinforcements.



	Specimen label	Maximum Load (N)	Compressive Strength (MPa)	Compressive strain at Maximum Comp. load (mm/mm)	Load at Maximum Comp. load (kN)
1	Base	38077.67	336.68	0.50478	-38.07767
Mean		38077.67	336.68	0.50478	-38.07767
Standard Deviation		-----	-----	-----	-----
Minimum		38077.67	336.68	0.50478	-38.07767
Maximum		38077.67	336.68	0.50478	-38.07767
Range		0.00	0.00	0.00000	0.00000

	Modulus (Automatic) (MPa)	Axial Gauge Length (Strain Source) (mm)	Comment
1	1439.50908	-18.00027	
Mean	1439.50908	-18.00027	
Standard Deviation	-----	-----	
Minimum	1439.50908	-18.00027	
Maximum	1439.50908	-18.00027	
Range	0.00000	0.00000	



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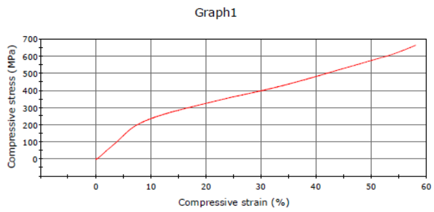
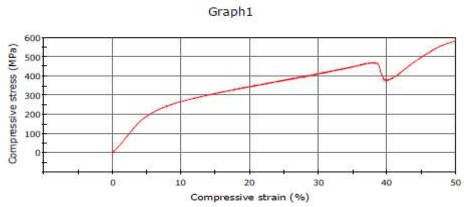
Range	0.00000	0.00000	

Figure 4: Compression Data INSTRON Model: 8801 for A356 Aspect Ratio of 1.0 and 1.5.



	Specimen label	Maximum Load (N)	Compressive Strength (MPa)	Compressive strain at Maximum Comp. load (mm/mm)	Load at Maximum Comp. load (kN)
1	G2_4_1:1	74936.50	662.58	0.58015	-74.93650
Mean		74936.50	662.58	0.58015	-74.93650
Standard Deviation		-----	-----	-----	-----
Minimum		74936.50	662.58	0.58015	-74.93650
Maximum		74936.50	662.58	0.58015	-74.93650
Range		0.00	0.00	0.00000	0.00000

	Modulus (Automatic) (MPa)	Axial Gauge Length (Strain Source) (mm)	Comment
1	2487.83485	-12.00047	
Mean	2487.83485	-12.00047	
Standard Deviation	-----	-----	
Minimum	2487.83485	-12.00047	
Maximum	2487.83485	-12.00047	
Range	0.00000	0.00000	



	Specimen label	Maximum Load (N)	Compressive Strength (MPa)	Compressive strain at Maximum Comp. load (mm/mm)	Load at Maximum Comp. load (kN)
1	G2_4_1:1.5	65937.66	583.02	0.49892	-65.93766
Mean		65937.66	583.02	0.49892	-65.93766
Standard Deviation		-----	-----	-----	-----
Minimum		65937.66	583.02	0.49892	-65.93766
Maximum		65937.66	583.02	0.49892	-65.93766
Range		0.00	0.00	0.00000	0.00000

	Modulus (Automatic) (MPa)	Axial Gauge Length (Strain Source) (mm)	Comment
1	3529.47094	-18.00060	
Mean	3529.47094	-18.00060	
Standard Deviation	-----	-----	
Minimum	3529.47094	-18.00060	
Maximum	3529.47094	-18.00060	
Range	0.00000	0.00000	

Figure 5: Compression Data INSTRON Model: 8801 for A356 with 2% Graphite + 2% Granite Dust Aspect Ratio of 1.0 and 1.5.

Figure 6: Al-Si alloy Specimens showing Bulge profiles at various Deformation stages under Compression Testing at aspect Ratio (a)1.5 and (b)1.0.

4. RESULTS AND DISCUSSIONS

4.1 Compressive Behaviour

"Compressive properties of the alloy and composites are studied from the load-displacement curves. Figure 7 and Figure 8 shows the true stress–true strain curves of alloy and composites with aspect ratios of 1.0 and 1.5 respectively.

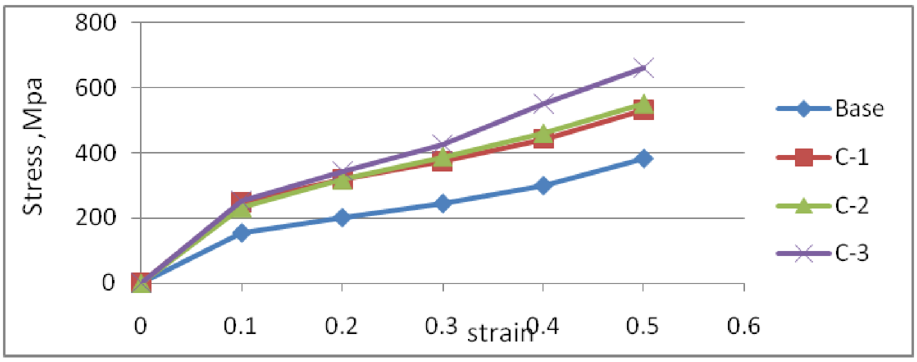


Figure 7: Variation of Compressive Stress and Strain in Al-Si Alloy and Composites (Aspect Ratio 1).

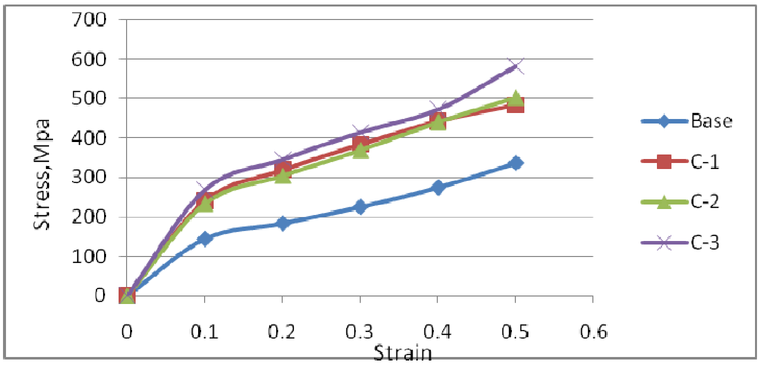


Figure 8: Variation of Compressive Stress and Strain in Al-Si Alloy and Composites (Aspect Ratio 1.5).

Both alloy and composites exhibit strain hardening behaviour showing increase in load with increasing displacement. The composites show higher loads than the alloy and also the increase in load will increases with the increasing reinforcement contents, indicating increased work hardening due to the presence of reinforcements and its corresponding weight fractions.

Erik Parteder [4], Khlaghi F [5] and Valdez S [6], reported, the strength of the MMC is expected to increase by addition of solid particles due to the strengthening effects occurred in particulate reinforced composites. These effects include the transfer of stress from the matrix to the particulate, the interaction between individual dislocations and particulates, grain size strengthening mechanism due to reduction in composite matrix grain size, and generation of a high dislocation density in the matrix of the composite as a result of the difference in thermal expansion between the metal matrix and particulates.

Figure 9 and Figure 10 shows the effect of aspect ratio1 and 1.5 on loads taken by the specimen up to 50% deformation. The increase in aspect ratio decreases the load required for the same amount of deformation. For a fixed diameter, a shorter specimen would force a bigger axial force to provide a similar proportion of reduction tall, as a result of the comparatively larger undeformed region [7].

From the below observations it is evident that stress of Al-Si alloy and its composites in the as cast condition increased with increase in degree of deformation in both samples of aspect ratio 1 and 1.5. Further it was also observed that the load required deforming Al-Si alloy & composites in the as cast condition increased with increase in reinforcement content as more over like ratio".

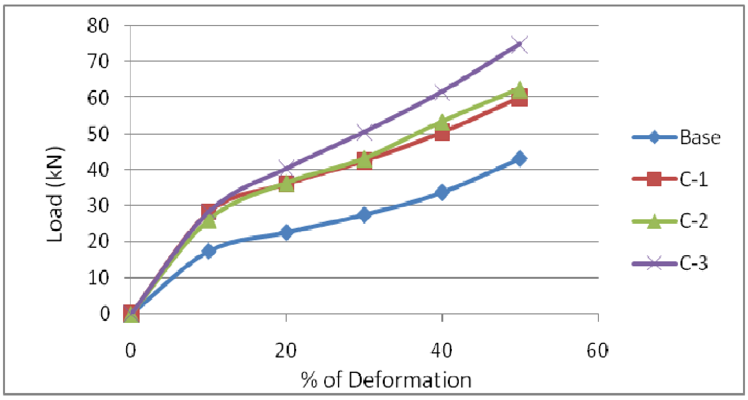


Figure 9: Effect of Load on Deformation of Samples with Aspect Ratio 1.

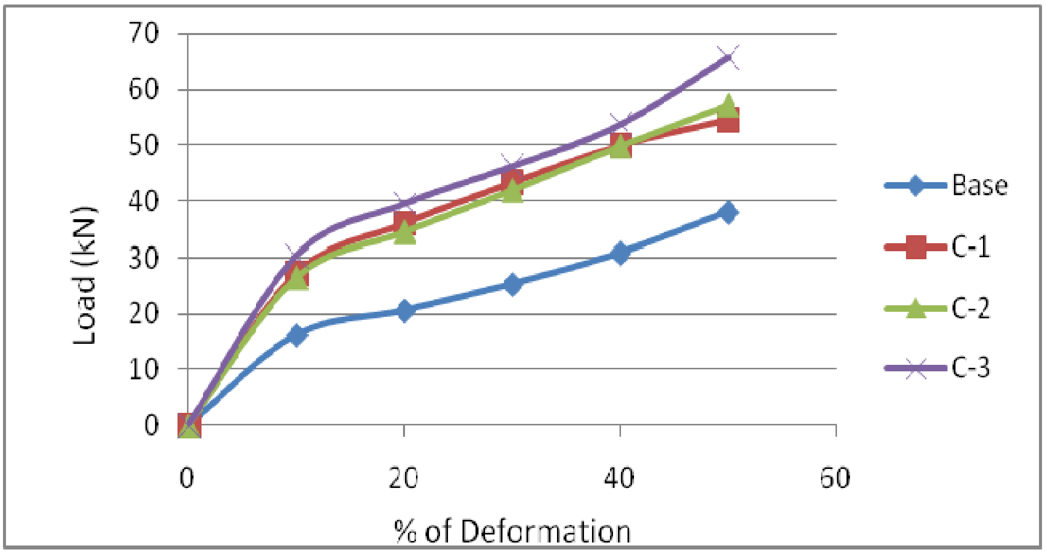


Figure 10: Effect of Load on Deformation of Samples with Aspect Ratio 1.5.

4.2 Hollomon Power Law Parameters

“In the absence of thermal action, like recrystalization or recovery, throughout the deformation method, the exponent 'n' was alive of the work hardening. This represents the rise of flow stress σ with increase in natural strain ε. Supported this phenomenon; the work hardening coefficient ‘n’ was a live of accomplishable most formability for various materials throughout forming with a similar external restraints, a better work hardening constant means that a better uniform elongation worth, thereby reducing the tendency for native straining within the material though slip planes sometimes cross grain boundaries, particularly if the crystals have twin orientation or on the brink of it as a rule deformation stops whenever a modification of orientation is present not only grain boundaries but also sub boundaries acts as barriers for movement, and a pile-up of dislocations with distortion of the crystal results [8–10].

The calculated true stress vs. true strain was fit into the equation of Holloman power law [7-10] given by:

$\sigma = K\varepsilon^n$-------(1) where σ = true stress, ε= true plastic strain, K= strength coefficient, n = strain hardening exponent,

Hollomon parameters ‘K' and ‘n' are used widely to assess the behaviour of metals in both uniaxial tension and compression at room temperature [11]. These constants have also been used to relate properties in metal forming [12-14]. The strength coefficient (K) gives the flow stress at unit strain and it is the measure of elastic spring-back. The strain hardening exponent ‘n' is an important parameter in metal forming. It signifies the strain hardening or works hardening characteristic of a material, that is, the higher the value of ‘n', higher is the rate at which the material work hardens. A material with a high value of ‘n' is preferred for a process which involves plastic deformation. The larger the ‘n' value, the more the material can deform before instability [15]. To validate the calculations, the plastic region of the curve. To study the effect of reinforcement content on strength coefficient (K) and strain hardening exponent (n), calculations have been made taking base alloy value as zero. Figure 11 and Figure 12. Shows the effect of reinforcement content on strength coefficient (K) and strain hardening exponent (n). As the reinforcement content increases, a continuous increase in ‘K’ values has been observed. Increased fabrication time of composites may be one of the reasons for the formation of a thick interface between the matrix and the reinforcement, inhibiting the effective transfer of load from the matrix to the reinforcement.

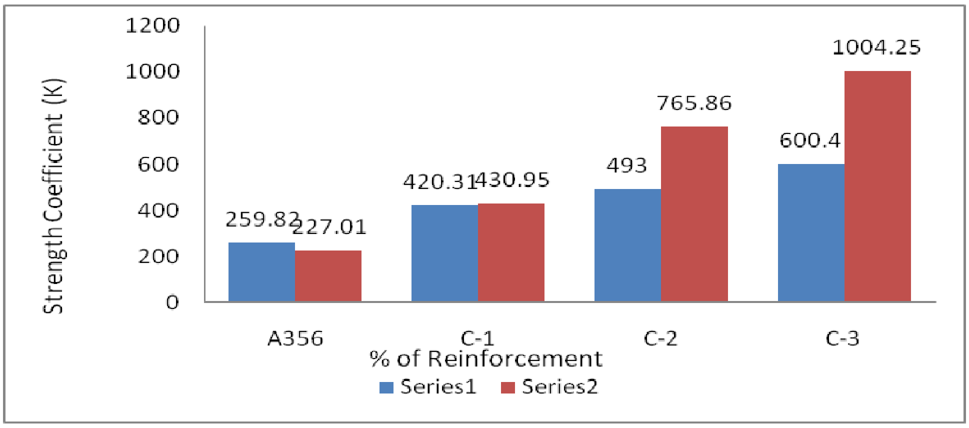


Figure 11: Variation of Strength Coefficient (K) with respect to Content.

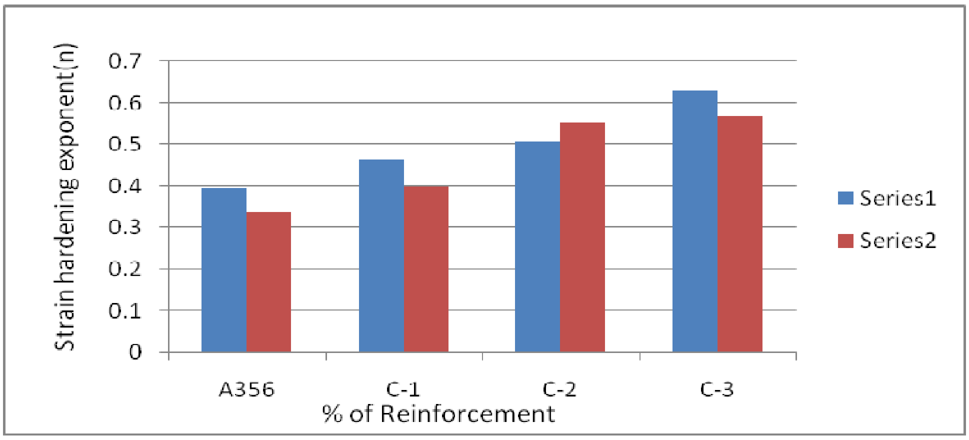


Figure 12: Variation of Strain Hardening Exponent (n) with Reinforcement Content.

It is evident that strength coefficient (K) and strain hardening exponent(n) of the Al-Si alloy and its composites in the as cast condition as well as after deformation has increased with increased reinforcement content in both samples of aspect ratio 1 and 1.5. But it was observed that the samples with aspect ratio 1 are found to have higher values of strength coefficient (K) and strain hardening exponent (n) than that of the samples with aspect ratio 1.5. Venugopal et al [16] reported that decrease in strength coefficient (K) value is due to the occurrence of bulk-forming & mass constancy. Composites with higher reinforcements offer higher resistance towards deformation. Narayanaswamy R [17] reported that composites with smaller particles offer higher value of strength coefficient. Samuel K G et al [18] reported that the larger the strain hardening exponent (n) value, the more the material can deform before instability. A material with a high value of n was preferred for a process, which involves plastic deformation. The strain hardening exponent found to be increasing with an increase in aspect ratio. The increase in strain hardening exponent (n) with increasing aspect ratio shows the material can take more plastic deformation before instability.

An effective interface is one which transfers quickly from the matrix to the reinforcement in a smooth way, and this effectiveness holds good only when a uniform interface is formed between the matrix and reinforcement. Formation of thicker interfaces not only impedes load transfer (diminishing ‘K') but also minimizes the dislocation mobility (diminishing ‘n'). Hollomon parameters ‘K' and ‘n' are used widely to assess the behavior of metals in both uniaxial tension and compression at room temperature [19-20]. These constants have also been used to relate properties in metal forming [21-23]. The strength co-efficient (K) gives the flow stress at unit strain and it is the measure of elastic spring-back. The strain

hardening exponent ‘n' is important in metal forming. It signifies the strain hardening or works hardening characteristic of a material, that is, the higher the value of ‘n', higher is the rate at which the material work hardens. A material with a high value of ‘n' is preferred for the process, which involves plastic deformation. The larger the ‘n' value, the more the material can deform before instability [15]. Strain hardening exponent (n) of the Al-Si+2%Graphite+4%Granite composites in the as cast condition has increased with increased reinforcement content in both samples of aspect ratio 1and 1.5. Further, it is also observed that the strength coefficient (K) and strain hardening exponent (n) of the Al-Si alloy composites decreased with increased aspect ratio”.

5. CONCLUSIONS

- “The stress of base Al-Si alloy and its Graphite/Granite composites in the as cast condition has increased with increase in deformation in both samples of aspect ratio 1 and 1.5.
- Load required deforming of base Al-Si alloy and its Graphite/Granite composites in the as cast condition increased with increase in reinforcement content as well as with aspect ratio.
- Strength coefficient (K) of Al-Si-2%Graphite/4%Granite considered in the present investigation is found to be 600.4 & 1004.25 of aspect ratio 1 and 1.5, shows that the material has good flow stress per unit strain compared to its base Al-Si alloy and its composites.
- Strain hardening exponent (n) of Al-Si-2%Graphite/4%Granite, considered in the present investigation, is found to be 0.63 and 0.57 of aspect ratio 1 and 1.5, shows that the material has good formability and can be work-hardened at a higher rate compared to base Al-Si alloy and its composites”.

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